Chapter 16

REST-OF-WORLD (ROW) SATELLITE SYSTEMS

For the longest time, space exploration was an exclusive club comprised of only two members, the United States and the Former Soviet Union. That has now changed due to a number of factors, among the more dominant being economics, advanced and improved technologies and national imperatives. Today, the number of nations with space programs has risen to over 40 and will continue to grow as the costs of spacelift and technology continue to decrease.

RUSSIAN SATELLITE SYSTEMS

In the post-Soviet era, Russia continues its efforts to improve both its military and commercial space capabilities. These enhancements encompass both orbital assets and ground-based space support facilities. Russia has done some restructuring of its operating principles regarding space. While these efforts have attempted not to detract from space-based support to military missions, economic issues and costs have lead to a lowering of Russian space-based capabilities in both orbital assets and ground station capabilities.

The influence of Glasnost on Russia's space programs has been significant, but public announcements regarding space programs focus primarily on commercial space promotion and budgetary justification of the civil and commercial space programs. Admissions of their military use of space remain infrequent, and the economic measures reported by space program managers, appear to be designed largely to avoid calls for further constraints.

Despite restructuring throughout the Russian military, the objectives of the military space programs have not changed. Military space strategy still requires sufficient capability to provide effective space-based support to terrestrial military forces and the capability to deny the use of space to other states. Maintaining this capability has, however, proved extremely difficult in post-Soviet Russia.

Missions and Operations

The satellite section of the Russian space program continues to be predominantly military in character, with most satellites dedicated either to exclusive military missions (such as reconnaissance and targeting) or to civil/ military applications (such as communications and meteorology). A large portion of the Russian space program is kept running by launch services, boosters and launch sites, paid for by foreign commercial companies.

The most obvious change in Russian space activity in recent years has been the decrease in space launches and corresponding payloads. Most of these launches are for foreign payloads, not Russian. This can be attributed not only to the recent breakup of the Soviet Union, but also to the fact that Russian satellites are gradually becoming more sophisticated and longer-lived. This increased operational efficiency is the mark of a more mature military space program which can reduce redundancy while accomplishing its missions. Economic problems throughout Russia have lead to many problems in building and launching these new satellites. While Russia retains the surge launch and reconstitution capabilities that are essential for military operations in crisis or conflict, money and lack of maintenance to ground facilities cast doubts on the viability of this former Soviet capability.

Space-Based Military Support

An extensive array of spacecraft was developed to support the Soviet, now Russian, armed forces and political leadership. These satellite systems conduct missions which include: imagery; electronic and radar reconnaissance; launch detection and attack warning; ocean surveillance and targeting; command, control, and communications; geodetic, navigational, and meteorological support; anti-satellite (ASAT) operations; and military R&D. Reports in 1999 indicate that Russia's military space forces have barely the resources to meet the needs of the nation's armed forces.

These systems, in turn, are supported by a tremendous infrastructure on the ground, including the Ministry of Defense (MOD) main space command, control and telemetry complex near Moscow. Improvement, maintenance and refurbishment of this infrastructure has continued despite a lower launch rate. Plans are ongoing to streamline the command and control systems, both civil and military, to optimize the networks.

Russian sources have stated that more that 70 percent of the spacecraft and ground facilities active in 1999 have outlived their guaranteed service lives.

Anti-satellite Systems

The Russian military and political leadership is fully aware of the value of military space systems. They have developed the capability to disrupt and destroy the military space systems of potential enemies. Russia has a dedicated ASAT system that probably became operational in 1971. In August 1983, Moscow announced a unilateral moratorium on the launch of ASAT weapons. However, Russia continued the testing of ASAT elements and procedures on the ground, and the associated booster, the SL-11. The SL-11 is also the same booster used to launch the ELINT Ocean Reconnaissance Satellites (EORSATs) and Radar Ocean Reconnaissance Satellites (RORSATs), although the last RORSAT launch was in 1988. The co-orbital interceptor has been launched from two separate cosmodromes; Plesetsk in Russia and Tyuratam in Kazakhstan. Due to the current political considerations between Russia and Kazakhstan, it is doubtful that Russia would launch an ASAT system from Tyuratam. No Russian ASAT has been launched since 1982.

Russia maintains a significant ASAT capability against low-earth and medium-earth orbit satellites, but capabilities against high altitude ones are limited. Future ASAT developments could include new directed energy weapons or direct-ascent non-nuclear interceptors.

In addition to the co-orbital interceptor, Russia has additional potential ASAT capabilities. These capabilities include: exo-atmospheric ABM missiles, located around Moscow, that could be used against satellites in near-earth orbit; at least one ground-based laser, that may have sufficient power to damage some unprotected satellites in near-earth orbits; and electronic warfare assets that probably would be used against satellites at all altitudes. Research and development of technologies applicable to more advanced ASAT systems continue. Areas of investigation that appear to hold promise include high energy laser, particle beam, radio frequency and kinetic technologies.

Photographic Reconnaissance

Photographic reconnaissance by satellite to gather high resolution images of military installations and activities was so clearly of value to both the East and West that its development was one of the main incentives in the early years of the space era. Russia has both the older film return systems and newer digital, near-real-time, imaging systems. As with most of its satellite programs, Russian capability here has declined since the break-up of the Soviet Union. During the 1980's the Soviet Union launched over 30 photo-reconnaissance satellites, always having at least one imagery satellite in orbit. Russia currently has not been able to maintain anything near this rate. In fact, between September 28, 1996 and May 15, 1997, there were no Russian imagery satellites in orbit.

Russia's COSMOS film return "spy" satellites (**Fig. 16-1**) normally operate in low orbits that pass over geographic areas of interest. These satellites are designed to withstand the heat of reentry so that they can be recovered. They are used mainly for military purposes, but do have civilian uses.

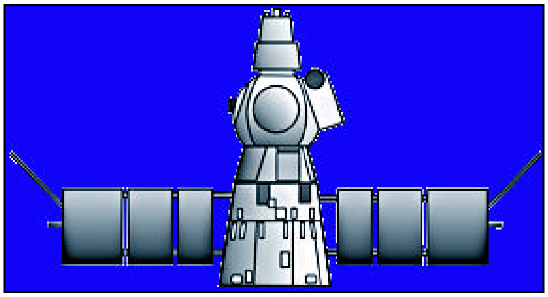

Fig. 16-1. Cosmos

A current commercial venture is using older Russian film return satellites to image areas of the earth for commercial sales. The imagery is processed at a resolution of two meters and then digitized and made available for sale via Internet. This project is a joint Russian-US venture called SPIN-2 (SPace INformation - 2 meter).

Communication

Russia operates several communications satellite systems. These satellites operate in highly inclined, geostationary and low-earth orbits.

The Molniya (Lightning) satellite series orbits in a highly inclined orbit that places it over the Russian landmass for approximately eight hours of its 12 hour orbit. With satellites placed 90 degrees apart, 24 hour communications are possible. This series was first launched in 1965. The Molniya-1 series are primarily used for military and government communications (**Fig. 16-2**). The Molniya-3 series are for civil and domestic telecommunications as well as TV broadcasts.

The Ekran (Screen), Gorizont (Horizon) and Raduga (Rainbow) series, were the Soviet Union's first generation of geosynchronous satellites. Launched in 1976, the Ekran was the Soviet Union's first geostationary communications satellite, providing direct TV broadcast to Siberia.

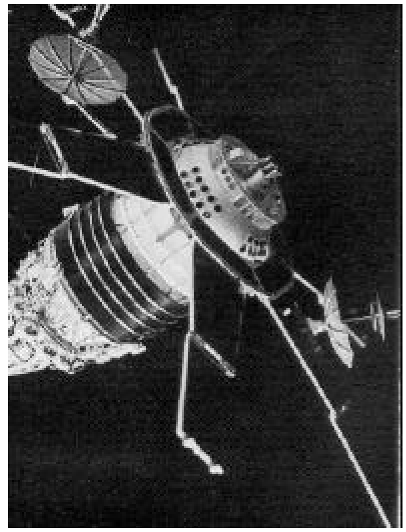

Fig. 16-2. Molniya 1 Communications Satellite

Gorizont was the next geostationary system, first launched in 1978 (**Fig. 16-3**). This constellation is mainly used for TV distribution, telecommunications services and maritime/mobile aeronautical receivers in western regions of Russia via the Moskva system. The Ruduga is believed to be very similar to the Gorizont series, but includes military and government communications channels in addition to domestic links. The first Ruduga was launched in 1975.

These systems are being replaced by newer generations of geostationary satellites. The Ekran is being replaced by the Gals series while the Gorizont follow-on is the Express system.

Russia has one additional geostationary system, a Satellite Data Relay Network (SRDN) with the satellite sometimes referred to as Luch or Loutch. This system was intended to relay communications between manned satellites and ground controllers. First launched in

1985, they were used extensively to relay communications with the MIR space station and the manned Soyuz spacecraft. It was also used to support the test flight of the Russian space shuttle Buran in 1988. In 1992, Russian press reported that MIR was operating without satellite links due to cost, leaving the station out of contact with ground control for up to 9 hours a day. Currently there is only one operational SRDN satellite in orbit. This is used by the MIR during special events, such as space walks and docking operations.

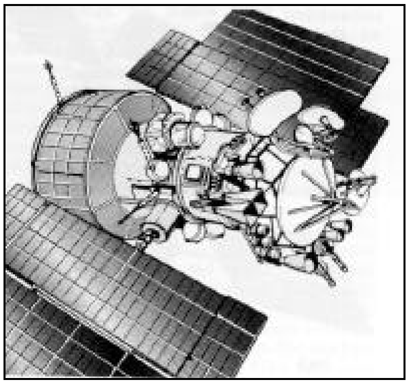

Fig. 16-3. Gorizont Communications Satellite

Russia also has many other communication satellites in lower orbits used primarily for military communications. There are a variety of systems, most launched in multiples of six or eight at a time. These systems often use a store and dump method of communications, receiving transmissions from locations around the world and storing the messages until over a Russian receiving station. A version of the sextet system without the military transponders was offered commercially in 1990 to foreign buyers interested in establishing their own store and forward communications networks. This system is marketed under the name Gonets.

Of all the Russian satellite systems, the communications constellations are in the best shape. These systems are, however, showing their age and those in orbit need to be replaced by current or upgraded systems. This problem has been highlighted by the launch failure of the last two attempts, 1996 and 1999, to place a Raduga in orbit.

Navigation

Russia maintains three satellite navigational systems: a low altitude military, a low altitude civil and GLONASS.

The low altitude military satellites, Parus (sail) provide primary navigational support to their maritime forces. The civil system has two different versions. The original version is Tsikada while the version with a Cospas/Sarsat search and rescue transponder is called Nadezhda (Hope). **(Fig. 16-4)**

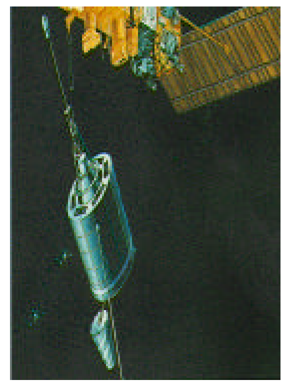

Fig. 16-4. Nadezhda

The GLONASS (Global Navigation Satellite System, Globalnaya Navigatsionnaya Sputnikovaya Sistema) system is similar to the U.S. GPS satellite navigation system. Like the GPS, GLONASS has many civil applications and commercial receivers are available (**Fig. 16-5**).

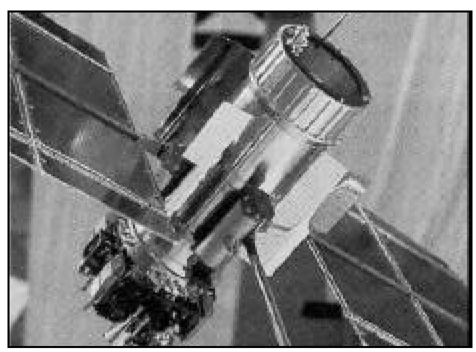

Fig. 16-5. GLONASS Navigation Satellite

While the Parus and civil systems have had regular replacement launches and are in good shape, the GLONASS system is not. Designed to operate with a constellation of 24 satellites, first achieved in December 1995, satellites have reached the end of their operational live and have not been replaced. Currently the

GLONASS system is operating with only 15 satellites. This is barely adequate for Russian military needs but without regular replacements in the near future, the system may breakdown and be unable to perform its mission by the year 2001.

Meteorological and Natural Resources

Russia's weather satellites provide them with vital environmental information including cloud coverage of earth; the flow of radiation in near-earth space; and atmospheric dust formations.

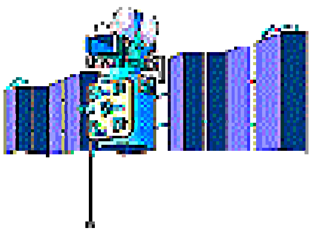

Fig. 16-6. Elektro

Russian maintains both geo-stationary (Elektro) **(Fig. 16-6)** and polar orbiting (Meteor) weather satellites. The Meteor system was first launched in 1969 while the geo-stationary Elektro was not launched until 1994.

Their natural resource satellites collect and analyze data covering a wide range of areas. These include agriculture, forestry, geology, mineral surveys, hydrology, oceanography, geography and environmental control. Natural resource data can be collected by photo-reconnaissance satellites, manned MIR missions and by oceanographic satellites.

Early Warning

Russian early warning satellites are used for detection of ballistic missile launches. The first system, Oko (eye) was placed in Molniya orbits allowing Russia to view the continental U.S. First launched in 1972, this system reached full operational capability of nine satellites in 1987. Four early warning satellites have been placed into geosynchronous orbits (1975, 1984, 1985 and 1987) to develop geo-stationary technologies and to provide coverage over ocean areas for submarine launched missiles. In 1988, a new series of early warning satellites, Prognoz**, (Fig. 16-7)** took over the geosynchronous location.

As with many of Russia's satellite systems, the early warning constellation is not fully operational. In 1999, only three of the nine Oko slots were filled. These three satellites orbit the Earth every 12 hours in highly elliptical orbits, but are unable to see the U.S. missile sites for about seven hours during each orbit. One Oko and one Prognoz are currently in geo-stationary orbit to cover the Atlantic and Pacific Ocean.

Fig. 16-7. Prognoz

ELINT Reconnaissance

Russia also has satellites to gather Electronic Intelligence (ELINT). Their task is to identify and locate military radio and radar stations, making it possible to identify command and control centers, forward battle elements, air defense units and reveal military movements. There have been several types of ELINT satellites, although only two types are thought to be currently deployed.

Ocean Reconnaissance

The primary function of ocean reconnaissance satellites is to detect, locate and target U.S. and Allied naval forces for destruction by anti-ship weapons. Two satellites that performed this mission are the ELINT Ocean Reconnaissance Satellite (EORSAT) and the Radar Ocean Reconnaissance Satellite (RORSAT - no longer active). These systems are designed to work in pairs, their combined data building a comprehensive view of surface activity. The RORSAT has an active search system which can locate ships in all weather conditions, while the EORSAT is a passive collector of transmissions from both radio and radar units.

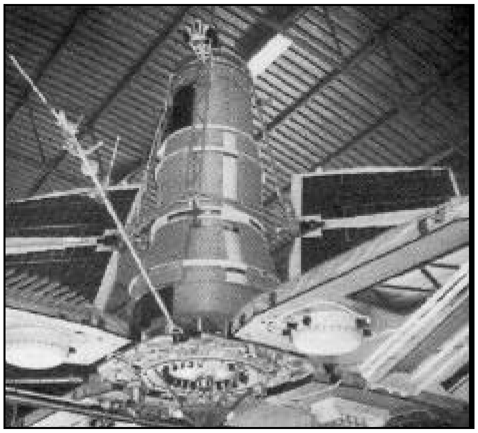

Fig. 16-8. Okean Oceanographic Satellite

A third satellite with a more civilian mission is the Okean. Its primary mission is ice and oceanographic reconnaissance (**Fig. 16-8**).

Another category includes "minor military" satellites. These satellites have missions of radar calibration, atmospheric drag measurement and spacecraft technology experimentation.

Scientific Satellites

Russia launches some scientific satellites that have instruments to study physical activity such as shock waves and solar wind. Some satellites that contain living organisms are launched to study biological conditions in space.

Man and Man-related Space Programs

Manned Russian programs include the MIR (Peace) space station (**Fig. 16-9**), whose core was launched in 1986. This complex provides a space-based science lab to conduct military and civilian experiments. The first addition to MIR was the *Kvant-1* module in 1987, containing astrophysics instruments, additional life support and attitude control equipment.

After a four month hiatus in mid-1989, the MIR space station complex was remanned and reactivated in early September. The space station has been continuously occupied since then. The MIR's capabilities for military and scientific research were vastly enhanced by launching the 20-ton *Kvant-2* module in late November of 1989. As part of its equipment, the *Kvant-2* carries an external gimbaled platform outfitted with a variety of sensors. Reporting indicates that these sensors are for earth resource studies only; however, military applications are also possible. *Kvant-2* has a larger hatch for egress into space. It also delivered a manned maneuvering unit to the MIR.

Kristall, the materials technology module, was added to the MIR complex in June 1990 to facilitate the production of various materials under microgravity conditions. Such materials have civil applications as well as military.

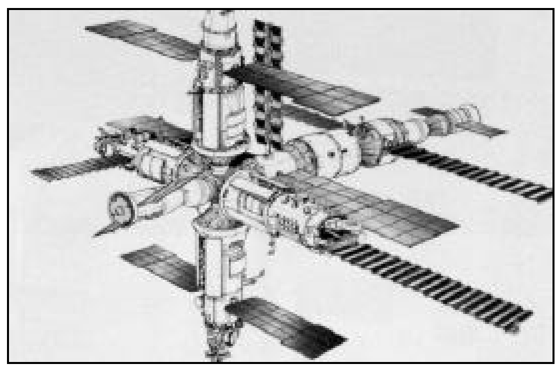

Fig. 16-9. MIR Space Station Complex

Kristall also has a docking port, originally designed as a potential means of docking the Russian space shuttle orbiter. It is now attached to the Docking Module used by the U.S. shuttle fleet.

In 1995, the *Spektr* module was added to the station. The focus for this module is Earth observation. Both Russian and American equipment are carried on-board the *Spektr*. This module also has additional solar panels to increase the power capability of the MIR space station.

With the increase in international cooperation, arrangements were made for the U.S. Space Shuttle to dock with MIR. In June 1995, the U.S. shuttle docked to MIR for the first time. However, to make that possible, the MIR configuration had to be changed. During a spacewalk, Russian cosmonauts moved the *Krystall* module to give the shuttle enough clearance to dock. The module had to be returned to its original position after the mission. In November 1995, the shuttle delivered and installed a Docking Module to the *Krystal* module.

The latest addition was the *Priroda* module in April 1996. Its primary purpose is to add Earth remote sensing capability to the station. The module also contains hardware and supplies for several joint U.S.-Russian science experiments.

With the final assembly complete in 1996, the core module will have long exceeded its planned life of five years. The station has also become a critical platform for developing the International Space Station.

During 1997, MIR suffered several problems with internal systems. In February, there was a fire in the oxygen-generating system which was extinguished, followed in March by additional repairs to the oxygen-generating system. Also in March 1997, the crew had a partial power outage and encountered problems with the motion control system. During April 1997, an overheated carbon dioxide remover had to be shut down and a cooling leak repaired. Potentially, the most damaging event occurred in June 1997, when a Progress resupply vehicle collided with the *Spektr* module. This collision damaged the solar panels and created a leak in the module. The crew had to seal off the *Spektr* from the rest of the station to prevent total loss of air in MIR. This rapid sealing off involved disconnecting cables from the *Spektr* to the station, resulting in a loss of 50 percent of the stations power producing capability. Further, computer problems have put the future of the MIR into serious doubt.

MIR has survived in space for over 12 years and has been occupied continuously for almost 10 years. With the start of the International Space Station, ISS, in 1998, the future of MIR in unknown. While Russia would like to keep its space station in orbit, its commitments to support the ISS make it almost impossible to maintain support to both MIR and the ISS. The last MIR crew is scheduled to depart in 1999, and the deorbit of MIR should take place in 2000.

Russian Space Shuttle

The Russian shuttle Buran (Snowstorm) was launched in the fall of 1988 on an unmanned flight **(Fig. 16-10).** This was the second flight of the SL-17. Technical and financial problems in Russia have halted this program.

Solar System Exploration

Fig. 16-10. Buran

Russia has launched numerous probes to the Moon, Venus and Mars. Collection and return of soil samples from the Moon, mapping and other scientific experiments have taken place.

Both solar system exploration and earth orbit science missions have suffered under budget constraints. No new programs have started in recent years, or are likely to, and it has been a struggle for Russian to maintain operations of some already in orbit. Some of the current programs would not survive without foreign participation.

UKRAINE SATELLITE SYSTEMS

After Russia, Ukraine has the most active space program. Several booster and satellite manufacturing companies and subcontractors exist in Ukraine. Some of the old Soviet Union's satellite and space control sites are also located in Ukraine.

Ocean Reconnaissance

Ukraine currently operates only one satellite. Based on a Soviet ocean reconnaissance satellite, this Ukraine built satellite family is used for all-weather radar ice and oceanographic surveillance by both Russia and Ukraine. This satellite family is called Okean (Ocean) by the Russians. In 1995 a joint Russian/ Ukrainian project launched an Okean which the Ukrainians took over full operational control in late 1995. This program is called Sich by Ukraine. Improved versions of the Okean are planned by Ukraine. These versions when used exclusively by Ukraine will be known as Sich-2 and Sich-3.

EUROPEAN SATELLITE SYSTEMS

The majority of the satellites produced or launched by European nations have been for scientific research or communications (including television). Many of these projects are also multi-national in construction or usage. To cover all the countries in Europe and their various national and international programs is beyond the general scope of this publication.

Communications

The following European countries have communications/TV broadcast satellites:

- United Kingdom - Skynet series
- France - Telecom series
- Germany - DFS series
- Hungry - CERES
- Italy - Italsat series
- Luxembourg - Astra series
- Norway - Thor series
- Spain - Hispasat series
- Sweden - Siries

There are also several international communications satellites that Europe uses internationally:

- Eutelsat, European Telecommunications Satellite Organization, 47 members
- Inmarsat, International Mobile Satellite Organization, 79 members
- Intelsat, International Telecommunications Satellite Organization, 136 members

Earth Resources

ERS Series

The European Remote Sensing (ERS) satellite system has three different radar sensors for all-weather sensing (**Fig. 16-11**). It is intended for global measurements of sea wind and waves, ocean and ice monitoring, coastal studies and a small amount of land imagery. An ESA project, the system had contractors throughout Europe.

Fig. 16-11. ERS - series Satellite

ERS-1 was launched in 1991, followed by ERS-2 in 1995. Both satellites are in a polar, low-earth orbit (LEO).

One of the first Synthetic Aperture Radar (SAR) commercial earth resource satellites, the demand for ERS-1 products exceeded the preparatory studies and surveys. The range of customers is enormous, from individual scientists to multi-institutional research groups and from small high-tech firms to multi-billion dol-

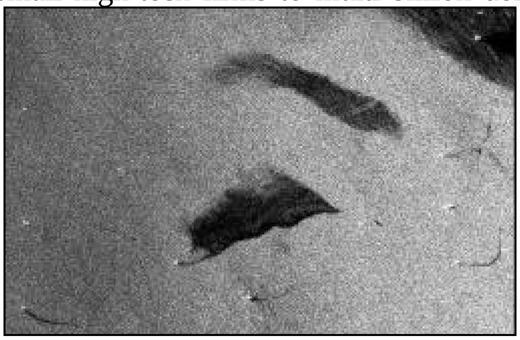

Fig. 16-12. North Sea oil spill detected by ERS

lar firms and large public services **(Fig. 16-12)**.

FRENCH SATELLITE SYSTEMS

Within the European community, France has the most active national satellite program. These programs include both commercial and military applications. In addition to communications, France has developed, launched and now controls earth resources, military imagery and a signals intelligence testbed satellite.

Earth Resources Satellites

SPOT Series

The Satellite Probatorire d'Observation de la Terre, SPOT, is an optical earth resources satellite (**Fig. 16-13**). The satellite was designed by CNES (Centre National d'Etudes Spatiales), the French National Space Center, and developed with the participation of Sweden and Belgium. The system comprises a series of spacecraft plus ground facilities for satellite control and programming, image production and distribution.

The exploitation is managed by CNES and SPOT Image. CNES is directly responsible for on-orbit control of the satellite and the execution of the acquisition plan. SPOT Image is in charge of pre-processing the image telemetry and producing the products. It is also responsible for the commercial exploitation of SPOT data. Receive locations for SPOT imagery are organized as two networks; a centralized network and a decentralized network (**Fig. 16-14**). The central network is comprised of the main imagery receiving stations at Toulouse, France and Kiruna, Sweden. The decentralized network consists of receive locations around the world having contracts with SPOT Image to receive SPOT imagery. The basic difference between the two networks is that the centralized stations can receive data recorded on the satellite,

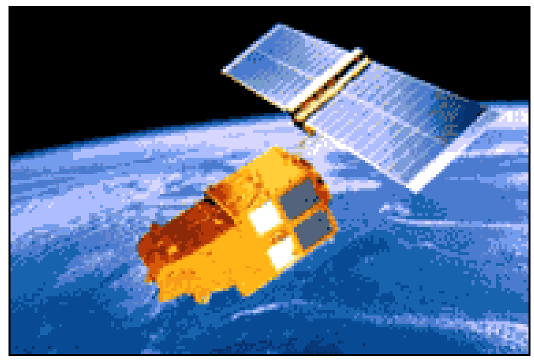

Fig. 16-13. SPOT Imaging Satellite

hence imagery of any part of the Earth. The other stations can only receive images directly from within their zone of visibility, a circle about 2,500 km around the station. This decentralized network consisted of twenty stations in 1997.

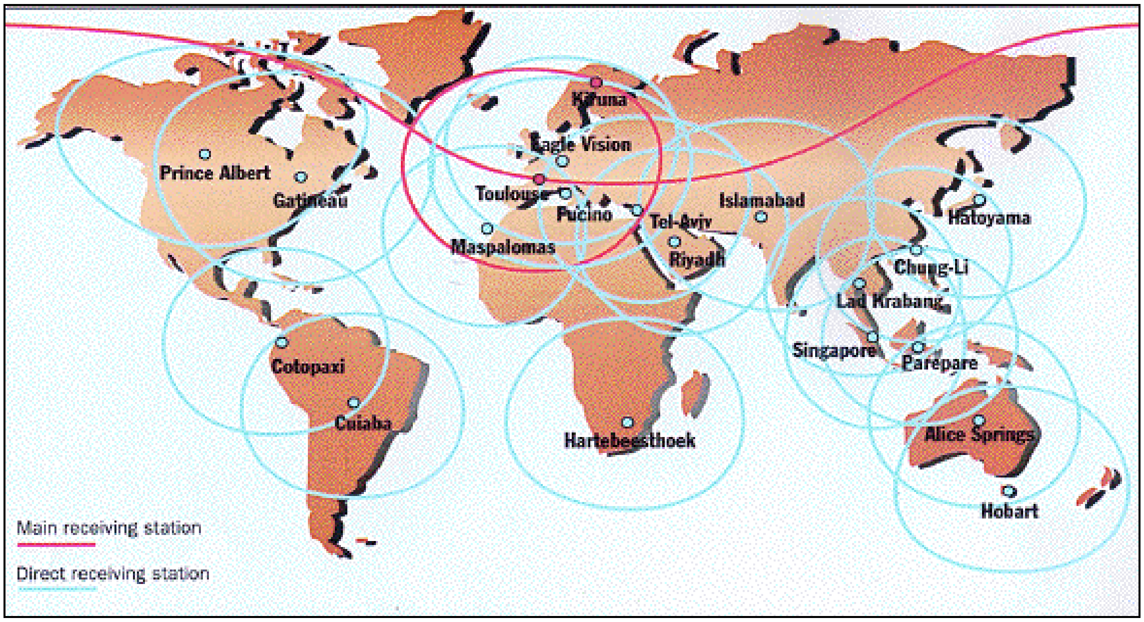

Fig. 16-14. SPOT Image Receive Stations

SPOT has two imaging modes, panchromatic and multispectral. The 10 meter resolution panchromatic (black & white image) is for applications calling for fine geometrical detail. The multispectral mode that images in three bands, green, red and near infrared, gives a color composite image. The imaging systems are capable of tilting the image viewing area to obtain stereo images.

SPOT-1 was launched in February 1986 and withdrawn from active service in December 1990. SPOT-2 was launched in January 1990 to replace SPOT-1. SPOT-3 was launched in September 1993.

Each satellite has a design life of three years; however, in the case of SPOT-1 and SPOT-2, they are proving to have a longer operational life.

In late 1996, at just over three years, SPOT-3 suffered an unrecoverable malfunction. SPOT-2 remained operational and SPOT-1 was reactivated in January 1997 to maintain SPOT coverage. Both SPOT-1 and -2 have inoperable data recorders and therefore, can only operate in the real-time acquisition mode. SPOT-4 was launched March 20, 1998. With SPOT-4 active, the SPOT system is now back to its full capability.

Military Systems

In December 1985, the French government approved the development of a military reconnaissance satellite for launch in the 1990's. The satellite would be based on the SPOT series with upgraded optics and recording systems. The development was aided by funding from Italy and Spain.

Helios

In July 1995, Helios-1A was launched into a 680 Km polar, sun-synchronous orbit. Helios provided the fourth independent military surveillance capability after those of the U.S., Russia and China. The imagery system is stated to be a multispectral, digital (near-real-time) camera with a one meter resolution.

NATO's 1999 air campaign in the Balkans has emphasized the importance of space systems. Several European nations are looking at national and joint efforts to improve European reconnaissance systems. Conditions in the Balkans also showed the need for radar and infrared reconnaissance systems. Helios-1A was the only non-US observation satellite used in the campaign. While the systems performance was publicly praised, in drove home the point of European reliance on U.S. systems. Many European governments feel they have to prepare for a time when European defense forces will be engaged in a conflict in which the United States does not take part and Europe must have its own assets. While seen as important, this development may take 10 to 15 years.

The launch of Helios-1B is planned for late 1999. Work is ongoing for the follow-on, Helios-2. This satellite is planned to include an infrared imaging system as well as an optical camera. The proposed time frame for a Helios-2 is around 2002.

CERISE

In addition to military imagery, France is beginning the development of an ELINT satellite reconnaissance capability. On the same launch as Helios in July 1995, the 50 kg CERISE (Caracterisataion de l'Environnement Radioelectriqur par un Instrument Spatial Embarque) was launched to help characterize the Earth's radio environment in research that could lead to a national ELINT satellite. The technology testbed had a designed lifespan of 2.5 years (**Fig. 16-15**).

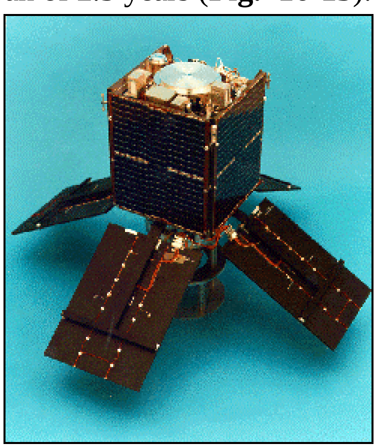

Fig. 16-15. CERISE

On 24 July 1996, ground controllers observed a sudden change in attitude of the CERISE. The satellite appeared to be tumbling rapidly end-over-end. Initial investigations suspected a collision with a piece of space debris. Subsequent observations and analysis seemed to confirm the collision of a section of a 10 year old Ariane rocket stage with the 6-meter long stabilization boom of CERISE. This is the first ever collision between two catalogued space objects. The collision is especially unusual because it was well documented by tracking systems and involved all European hardware (**Fig. 16-16**).

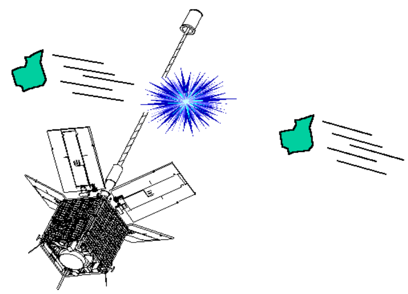

Fig. 16-16. Depiction of CERISE/Ariane collision

ASIA/PACIFIC SATELLITE SYSTEMS

Throughout Asian and Pacific Rim countries there are many satellite programs and users. Currently, only the Peoples Republic of China, Japan and India have satellite launch capability. As in Europe, many Asian and Pacific nations use international satellite systems in addition to buying satellites and launch services to place a satellite in orbit. Most of these satellites are for communications: radio, telephone or television. As with Europe, to cover all the nations in Asia and their various national and international programs is beyond the general scope to this document.

Communications

The majority of the satellites used by Asian and Pacific nations are communications systems. These systems are generally built and launched by another country. The following Asian nations have communications/TV broadcast satellites:

- Australia - 4 Optus satellites

- Hong Kong - 3 Asiasat, 3 Apstar
- Indonesia - 4 Palapa, 1 Cakrawarta
- South Korea - 2 Mugunghua
- Malaysia - 2 Measat
- Phillipines - 1 Agila
- Thailand - 3 Thaicom
- Singapore - 1 ST-1

JAPANESE SATELLITE SYSTEMS

Within Asia, Japan has the most extensive space program. Japan has the ability to build, launch and control space systems and satellites. Most Japanese launches have been Japanese scientific, communications and earth resources satellites. A major problem with the Japanese space program getting into the commercial market has been the cost of their launches.

Communications

The Japanese have several different communications corporations that own and control satellites. Most systems are located in geostationary orbits. These systems include:

- Broadcasting Satellite Systems, BSAT
  - 2 BSAT Satellites
- Japan Satellite Systems, JSAT
  - 5 JSAT Satellites
- Space Communications Corp, SCC
  - 3 Superbird Satellites
- Telecommunications Advancement Organization of Japan
  - 2 Broadcast Satellite (BS)
  - 2 N-Star

Earth Resources

Japan began Earth monitoring with weather satellites in 1977. Currently there are two Geostationary Meteorological Satellites (GMS), Himawari 4 and 5, in orbit over the Pacific Ocean. In addition to earth weather images, the satellites relay meteorological data from fixed and mobile stations within their field of view.

MOS series

Japan's first domestic earth resources satellite was the Marine Observation Satellite (MOS) launched in 1987. A second was launched in 1990. The MOS satellites were developed to acquire expertise for later operational systems. These satellites monitored atmospheric water vapor, ocean currents, sea surface temperature and ice floe distribution in addition to land applications. Sensors included a Multi-Spectrum Electronic Self-Scanning Radiometer (MESSR), a Microwave Scanning Radiometer (MSR) and a Visual and Thermal Infrared Radiometer (VTIR). Both satellites are now out of service, MOS-1B ending its mission life in May 1996.

JERS series

The Japan Earth Resources Satellite (JERS) was the second domestic remote sensing satellite and the first to operate at all-weather radar wavelengths (**Fig. 16-17**). The synthetic aperture radar (SAR) is accompanied by an optical sensor. The JERS-1 was launched in February 1992. The SAR system has a resolution of 18 meters and is used for monitoring land use and type, glacier extent, snow cover, surface topography, ocean currents and waves. The four band optical sensor covers the visible and near infrared region. It

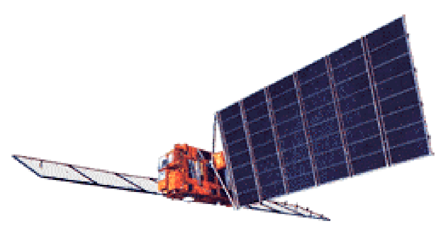

Fig. 16-17. JERS-1 satellite

is used for pollution monitoring in oceans and lakes, land use classification, cloud and snow discrimination. Imagery can be stored on board and transmitted to the main processing site in Japan or imagery of a local area can be sent real-time to other ground sites located in Asia, Europe, North America and Antarctica.

Launched in February 1992, the mission on JERS-1 was to last only two years, but it was operational and obtaining observation data on the earth for six-and-a-half years. Operation of JERS-1 was terminated on October 12, 1998 after a malfunction the day before.

ADEOS series

Japan's latest earth resources satellite is the ADEOS (Advanced Earth Observation Satellite) launched in August 1996. This satellite acquired global observation data corresponding to environmental changes, such as global warming, depletion of the ozone layer, decrease of tropical rain forests, occurrence of unusual weather and other tasks. Payload included both Japanese and foreign sensors.

In June 1997, the satellite developed major power problems and is now totally out of service with little hope of recovery. Studies are underway to determine the problem prior to the launch of ADEOS-2.

CHINESE SATELLITE SYSTEMS

The Chinese space program is developing a wide variety of satellites. Much of the development is slow, as the Chinese have limited access to Western or Russian technology. They are working on communications, earth resources/ imagery, weather, and science/space research.

Communications

STTW and DFH series

The STTW series are generally the test version of their communications satellites, the DFH series are the final. Sometimes, both designations apply after a satellite reaches orbit and is declared operational. China has successfully launched and operated both its DFH-2, a spin stabilized satellite, and the DFH-3, a three axis stabilized system.

During the mid-to-late 1990's, China had problems with both its booster and satellites. The DFH-2 series was to be replaced by the newer DFH-3. Three DFH-3 satellites were lost or became non-operational after only a short time in orbit (1994, 1996, and 1997). During this timeframe the DFH-2 satellites also were becoming non-operational. To get over the communications problems caused by the DFH-3 program, China has had to buy older satellites already on orbit or order western built systems

Currently China has three communications satellites, all foreign built, in operation.

With the return of Hong Kong to China control in July 1997, the satellites controlled from there, APStar and Asia-Sat, may in the future be included as Chinese systems. Currently these satellites are still controlled by the commercial companies that bought them. Of note is that the Chinese government owns75% of APStar.

Earth Observation

FSW series

The FSW series are recoverable satellites **(Fig. 16-18)** used primarily for imagery, military reconnaissance/earth resources starting in 1975. Since 1987, Micro-gravity experiments have also conducted using the FSW capsules. China has launched 17 of these flights, several of them containing foreign micro-gravity experiments.

Fig. 16-18. FSW capsule

FY Series

This series was China's first weather satellite attempt. The FY-1 series are polar orbiting, while the FY-2s are placed into geosynchronous orbits.

China launched two FY-1 satellites, only one of which is still operational. One FY-2 was launched in June 1997 but ceased operations in April 1999.

ZY-1 Series (CBERS)

In 1988, China and Brazil signed a co-operative program to develop two earth resources satellites. The program is called Zi Yuan (resource) in China and in Brazil and elsewhere the China-Brazil Earth Resources Satellite (CBERS). The first satellite is scheduled to launch in mid-1999.

INDIAN SATELLITE SYSTEMS

India, with more than three-quarters of its population dependent on agriculture, concentrates its space development activities on related applications satellites. The two prime goals involve operational space-based remote sensing and communications satellites.

Communications

INSAT series

India's first communications satellite was built by the U.S. and uniquely provided for simultaneous domestic communications and earth observation functions, primarily meteorology. The INSAT-1 series were launched between 1982 and 1990. INSAT-1A and 1C failed soon after launch. INSAT-1B was launched from the U.S. shuttle in 1983 and functioned until 1991. INSAT-1D is still operational in 1999.

The INSAT-2 series was built primarily by Indian companies and performs much the same functions as the INSAT-1 series. The INSAT-2A and INSAT-2B have increased communications capability from the INSAT-1. The INSAT-2C and 2D have additional communications capability but had their earth observation functions removed. Launched in July 1997, INSAT-2D failed in orbit during October 1997 due to an electrical fault. To replace this lost communications capability, India purchased already in orbit ARABSAT-1C from the Arabsat consortium in December 1997. The satellite was moved to an Indian orbital slot during the December-January time frame. The satellite was renamed INSAT-2DT and began operations in January 1998. INSAT-2E was launched in April 1999. This satellite is the last of the Indian built INSAT-2 series. In addition to the communications payload, this satellite again carries the earth observation/meteorology sensor.

Earth Resources

IRS Series

The Indian Remote Sensing satellite system (IRS series) is India's first domestic dedicated earth resources satellite. The first two satellites of this system carry the Linear Imaging Self Scanning (LISS) four band multispectral scanner. These bands are excellent for vegetation discrimination and land cover mapping. This system has a spatial resolution of either 72 or 36 meters. **(Fig. 16-19)**

IRS-1A was launched in 1988 and retired from routine service in 1995. IRS-1B was launched in 1991 and is still active. Imagery from these satellites is received in India and at other ground sites

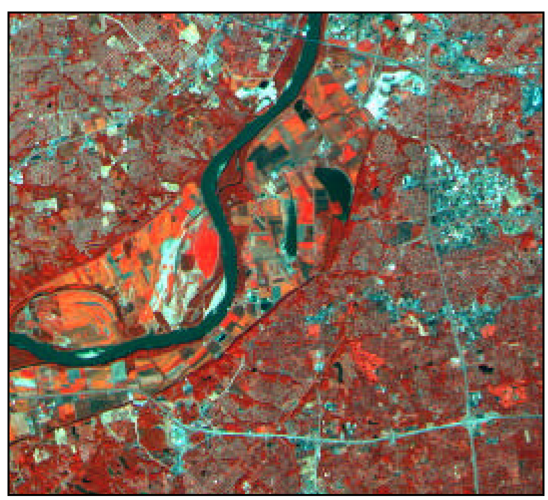

Fig. 16-19. IRS-1B LISS-2
36 meter resolution
Chesterfield, Missouri

Fig. 16-20. The Mall, Washington D.C. IRS-1C Panchromatic, 6-meter resolution

around the world. Information acquired can be used for many purposes, including monitoring droughts, providing timely area on crop yield assessments, vegetation discrimination, mapping of potential ground water zones and studies for potential irrigation, land use and land cover maps.

The next generation of satellites, the IRS-1C and 1D, carry the four band multispectral LISS-3 with a resolution of 23 meters; a panchromatic sensor with a resolution of 6 meters **(Fig. 16-20)**; and a two band Wide Field Sensor (WiFS) with a resolution of 188 meters. In addition, the 1C and 1D offer onboard recording, stereo viewing capability and more frequent revisits.

As part of developing both a satellite and launcher industry, India built multiple parts for their IRS satellites. These extra parts allowed India to gain additional expertise in satellite construction and gave them a useful payload to launch on their developmental PSLV space booster. The prime IRS-1 series would be launched on foreign boosters for safety, while the others would be part of the PSLV program. The first PSLV launch carried the IRS-1A's engineering model, refurbished and called the IRS-1E. This payload ended in the ocean when the PSLV's first launch on 20 September 1993 ended in failure.

The next PSLV test carried the IRS-P2, a demonstrator for the IRS-1C and 1D bus. This satellite was placed into orbit in October 1994. IRS-P3 was launched on the third PSLV test in March 1996. The payload included an improved three band WiFS sensor and an X-ray astronomy experiment provided by India as well as a German Modular Optoelectronic Scanner (MOS) for oceanographic applications.

In May 1999, India launched a new version of its IRS series, the IRS-P4 built for oceanographic research. This system carries the Ocean Color Monitor (OCM), an eight band spectral camera. The system collects data on chlorophyll concentration, phytoplankton blooms, atmospheric aerosols and water suspended sediments. Also on board is the Multifrequency Scanning Microwave Radiometer (MSMR). The MSMR operates in four microwave frequencies to collect sea temperature, wind speed, atmospheric water content. Now called Oceansat-1, it joined India's four other operational IRS satellites (IRS-1B, 1C, 1D, and P-3).

Additional IRS-P series satellites are planned to develop new and improved sensors. As the technology is developed, additional satellites will be produced and launched. Some of the planned systems include an ATMOS series for atmospheric observations, CartoSat for mapping and an improved IRS-2 series.

MIDDLE EAST/NORTH AFRICAN SATELLITE SYSTEMS

Throughout the Middle East and Africa there is only one nation with a complete space capability, Israel. Most other nations in this part of the world are currently only users of satellite systems, generally as part of a consortium. Egypt recently had a satellite built and launched that they are the prime users and sole controllers.

Communications

Most of the Middle East and Africa use of satellite systems has been for communications. IntelSat and Inmarsat have served those nations in this region that use satellite communications systems. Other than communications, earth resources receive stations are present in a few countries (Israel, Saudi Arabia, South Africa), some of which also have access to weather satellite data.

ArabSat series

The Arab Satellite Communications Organization (ASCO) was formed in 1976 to meet the increasing communications needs of the Arab countries. There are currently over twenty members across the Middle East and North Africa. The satellites used by ArabSat were built in Europe and America; launched into geostationary orbits by ESA and NASA; while Japan was the prime contractor for the ground receive sites.

ArabSat-1A was launched in February 1985, followed by ArabSat-1B in June. ArabSat-1A began drifting in late 1991 and was declared out of service in March 1992. ArabSat-1B followed a year later, starting to drift in October 1992 and declared out of service early 1993.

ArabSat-1C was launched in February 1992. It supports regional television, telephone, data and fax relay. In early 1993, only ArabSat-1C was operational, raising the possibility of leasing a satellite until ArabSat-2 was ready. Canada's Anik-D2 was selected, moved to cover the Middle East in 1993 and renamed ArabSat-1D. This satellite was operational until February 1995, when it depleted its fuel and was raised above geostationary. As ArabSat-2 was still not available, ASCO leased Telstar 301 in 1994. The satellite was moved late that year and renamed ArabSat-1E. This system also provides domestic telephone, data and television.

In 1996 the ArabSat-2 series was ready, with ArabSat-2A being launched in July and ArabSat-2B following in November. Arabsat-1E has ceased operations, while Arabsat-1C was sold to India. The next generation of satellites, Arabsat-3A was launched in February 1999. This newest satellite is dedicated to Direct TV Broadcasting with 20 Ku-band transponders. This gives ASCO a constellation of three satellites.

ISRAELI SATELLITE SYSTEMS

In addition to its own satellite programs, Israel also has receive stations for earth resource imagery from SPOT and the ERS series satellites. Israel also has international projects with European and Asian countries as well as NASA.

Communications

Israel has one communications satellite for which they were the prime contractor. In addition, they are uses of the Intelsat system, in which they hold a 1.06% share.

AMOS Satellite

The AMOS-1 (Affordable Modular Optimized Satellite, also referred to as the Afro-Mediterranean Orbital System) was launched by an ESA Ariane-4 in May 1996 into geostationary orbit. The transponders are optimized to cover the Middle East and Central Europe. The system performs broadcasting services of multiple digital television channels to Cable Headends, Direct-To-Home, business data and voice transmission to include interactive learning.

Israel is currently working on the AMOS-2/CERES (Central European Regional Satellite), a joint venture with Hungry. Launch of this new satellite is planned for late 1999 or early 2000.

Ofeq series

Israel's first satellite was the Ofeq-1 technology demonstration satellite, launched in September 1988. A second test satellite, Ofeq-2, was launched in April 1990. These first-generation satellites were spin stabilized and carried only test payloads.

Ofeq-3 (**Fig. 16-21**) was the debut of the second-generation of light Israeli satellites. Launched in April 1995, this satellite was also listed as a technology demonstrator, but unlike Ofeq-1 and 2, carried an operational payload. With a 3-axis stabilization system, the satellite is being proposed and marketed to carry payloads for astronomy and remote sensing. The payload carried on the Ofeq-3 is a light-weight electro-optical scanner or Earth Resources Monitoring System, which was developed in Israel. The Israeli media reported this as their first "spy" satellite.

In January 1998, Israel planned to launch Ofeq-4 to replace Ofeq-3, which was nearing the end of its planned operational life. This launch failed due to a malfunction of the booster soon after launch. Israel statements indicate that they will continue to develop, built, and launch earth observation/reconnaissance satellites.

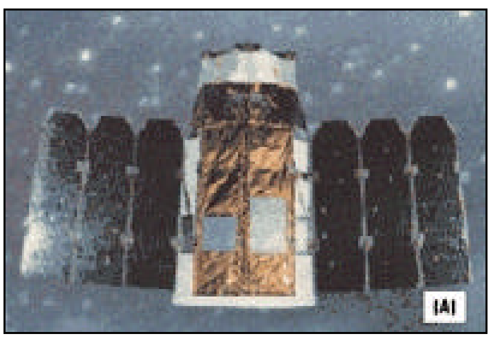

Fig. 16-21. Ofeq-3

Recent press reports indicate Israel is marketing Ofeq satellites and technology for commercial sales.

TechSat Series

TechSat is a collaboration to develop a simple, low cost, low power platform for technology testing. TechSat-1 contained an amateur store and forward transponder, an earth-observation digital camera, a spectroradiometer for ozone studies and an X-ray imager. This satellite was lost in March 1995 during the first attempted launch of Russia's Start booster from Plesetsk.

On July 10, 1998, TechSat-2 was launched on a Russian Zenit booster into a sun-synchronous 830 Km polar orbit. The 48 kilogram satellite contains a wide variety of experiments. They include a test of superconducting material that would allow satellites to carry more channels in a smaller space, a charged particle detector to determine frequency and damage of charged particle impacts, an ultraviolet sensor, an x-ray detector, a new stabilization system, and field test of a new horizon sensor.

In September, Israel announced that Techsat-2 had completed what is termed the first successful test of superconductive material in space.

OTHER MIDDLE EAST/AFRICAN SATELLITE USERS

EGYPT

Egypt has long been a member of the ArabSat and InmarSat communications organizations. In 1998, Egypt became the first Arab country and the first African nation to own and operate its own satellite. This TV, radio, and data transmission satellite will allow viewers throughout the Mediterranean and Middle East to have programs in a region previously dominated by Saudia Arabian and non-Arab broadcasters.

NileSat Series

NileSat 101, sometimes just NileSat-1 **(Fig. 16-22)**, was launched in April 1998. With this launch Egypt became the first Arab and African nation to own and operate its own satellite. The satellite was designed primarily for Direct-To-Home television but will also offer free and pay TV, audio (radio), data services, and other related services. With 12 transponders, the system is capable of transmitting at least 84 TV channels. NileSat 101 began transmitting programs at the end of May 1998.

Egypt also owns and operates the two Satellite Control Stations (SCS). The primary control Tracking, Telemetry and Control (TTC) station with its Satellite Control Center (SCC) is located near Cairo. A backup SCS is in Alexandria.

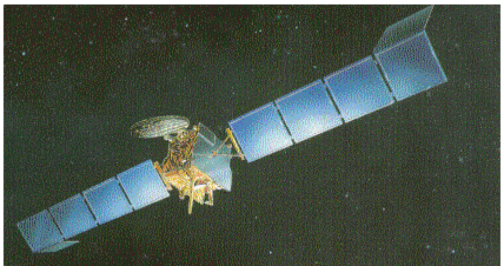

Fig. 16-22. NileSat 101

Egypt is considering a plan to launch a second satellite, NileSat 102. This new satellite would cover the African continent in an effort to promote cooperation among African countries in the media field.

AFRICA

Africa, long the world's most neglected satellite market, is finally being taken more seriously as a major market for all types of satellite services. No African countries have domestic satellites with the exception of Egypt, who controls a satellite built by someone else and South Africa, which controls a recently built university research satellite launched. Many African satellite users will use an upcoming Intelsat through the auspices of the Regional African Satellite Communications Organization. One dedicated satellite for Africa has been launched, which will beam radio programming directly to listeners throughout Africa.

AfriStar

Launched in October 1998, AfriStar is intended to provide high quality digital information, international news, and entertainment programs through Africa. Owned and operated by WorldSpace, a registered public charity, located in the United States. AfriStar will allow local African radio stations of all sizes to reach an audience on the whole of the continent. While the satellite will be controlled from the AfriSpace, Inc. regional operations in Washington D.C., programming can be sent to the satellite from ground stations in London, England; Toulouse, France; and Johannesburg, South Africa. Plans include the building of a studio in Africa that would be run by Africans with an African advisory board.

AfriStar is the first of three planned satellites intended by WorldSpace to provide digital audio communications to developing nations around the world. AsiaStar and AmeriStar are planned for launch in either late 1999 or in 2000.

SOUTH AFRICA

South Africa became the first African nation to have its own domestically built satellite placed in orbit. A program sponsored by the University of Stellenbosch, near Cape Town designed, built, and is controlling the satellite.

Sunsat

The Stellenbosch UNiversity SATellite or Sunsat is an educational and research project. In addition to carrying earth resources and communications payloads, the program was intended to encourage engineers and engineering in South Africa, and gain international recognition of South Africa's ability to contribute and compete in the high technology world.

The Sunsat carries both a three-color MSI imager and a commercial color video camera as earth resources systems. It also carries amateur radio gear, high school experiments, a US sponsored GPS receiver to conduct atmospheric, ionospheric and geodesic mapping, and other NASA sponsored experiments.

The 61 kilogram satellite, considered a critical milestone for the South African space program, was launched into a polar orbit in February 1999.

NORTH AND CENTRAL AMERICA

After the United States, Canada and Mexico are the only nations in North or Central America with any significant space capability.

Canada builds and controls its own satellites and was developing a privately funded space launch facility at Churchill, Manitoba. This launch facility has only launched sub-orbital flights to date and the private operator of the SpacePort announced it was going out of business in 1998.

Mexico is primarily a user of communications satellites. The first generation of US built satellites were the Morels series followed by the current Solidaridad series that provide telephone, data, TV distribution, and mobile services.

CANADIAN SATELLITE SYSTEMS

Telesat series

Canada has an extensive communications satellite system. The first satellite, Anik-A1 (also Telasat-1) was launched in November 1972. This was followed by Anik-A2 in 1973, Anik-A3 in 1975 and Anik-B1 in 1978.

The first of the Anik-C series, C3, was launched in late 1982, followed by C2 in June 1983. Anik-C1 launched in April 1985. Both C1 and C2 were sold to Argentina in 1994 to provide interim services until a dedicated system became available. Anik-D2 was launched in 1984 and then sold in 1993 to become ArabSat-1D.

The Anik-E series has suffered several mishaps. While both satellites, E1 and E2, are active and performing their mission, both have had technical problems that have reduced their capability.

Canada's latest satellite is the MSAT-1. This satellite was launched in April 1996. The system provides mobile telephone, radio, data and positioning service to land, aviation and maritime users.

Earth Resources

Canada uses several different earth resources satellite systems. The country has ground receive stations for ERS-1, JERS-1, Landsat and SPOT. In addition, Canada has developed and controls its own radar Earth resources satellite.

Radarsat

Radarsat is a cooperative program between the Canadian Space Agency (CSA), NASA and NOAA (**Fig. 16-23**). CSA built and operates the system, NASA furnished the launch vehicle and facilities. In exchange, U.S. government agencies have access to all archived Radarsat data and around 15% of the satellite's observing time.

Radarsat is a synthetic aperture radar (SAR) system with a resolution between 30 and 90 meters. The first Radarsat was launched in November 1995 into a polar orbit. It is designed to give primary coverage of Canada and the Arctic regions.

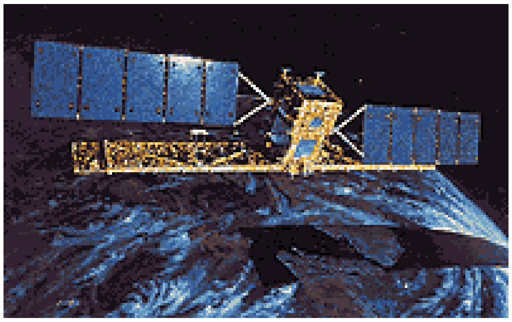

Fig. 16-23. RADARSAT

MEXICAN SATELLITE SYSTEMS

Mexico currently operates four communications satellites. Morelos-2 was launched in November 1985. Solidaridad-1 and -2 were launched in November 1993 and October 1994, respectively. The Morelos-2 provides domestic television, telephone and data services. The Solidaridad satellites provide these same services in addition to mobile and international services. Mexico's latest satellite is the SATMEX-5, which will provide a complete range of telecommunications services, direct TV broadcasting, rural telephony, distance learning and telemedicine to Mexico and Spanish-speaking communities in North and Latin America. This satellite was launched in December 1998.

SOUTH AMERICA

South America is served by a small number of dedicated satellites, however, service is also provided by a variety of trans-Atlantic, PanAmSat and other Atlantic Ocean satellites. Only Brazil and Argentina have their own communications satellites systems.

BRAZILIAN SATELLITE SYSTEMS

Brazil is the most advanced nation in South America involved in the space business. They are capable of manufacturing their own space launch vehicles and satellites and controlling them. Brazil's first space launch vehicle ended in failure 3 November 1997. One of the four strap-on engines failed to ignite and 65 seconds later, the launch controllers had to destroy it. The next launch is planned for late 1999.

Brazilsat series

Brazilsat-A1 and A2 were launched in February 1985 and March 1986, giving Brazil its own communications. The A1 satellite was sold in 1995 and the antenna re-aimed to North America. A2 is currently an on-orbit spare. These satellites carried limited television, telephone and data services.

The currently active communications satellites are the Brazilsat-B series. B1 was placed into geosynchronous orbit in August 1994, with B2 following in March 1995. This series increased the number of transponders over the Brazilsat-A series and added X-band transponders for government and military uses. The newest in this series, Brazilsat-B3A, was launched in February 1998

SDC series

The SDC series of Satellite Data Collectors are the first satellites built by Brazil. SDC-1 relays data gathered by ground-based data collection platforms throughout Brazil, which is then transmitted to an acquisition station. The SDC-1 was placed into orbit in February 1993 from the Pegasus (**Fig. 16-24**).

SDC-2A was planned for the first launch of the Brazilian space booster but was destroyed when the booster failed 65 seconds into the flight. In October 1998 the second of the series, SCD-2, was launched by a Pegasus booster.

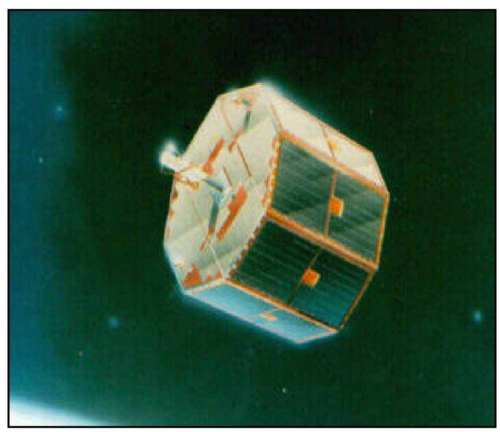

Fig. 16-24. SDC-1 Data Relay Satellite

Brazil has plans for other data relay satellites and is developing its own remote sensing programs. A joint Chinese-Brazilian Earth Resources Satellite, CBERS, is scheduled for launch in 1999. Currently, Brazil has ground stations to receive data from ERS-1, Landsat and SPOT.

ARGENTINE SATELLITE SYSTEMS

Argentina's space activities emphasize applications. A user of Inmarsat and Intelsat, Argentina, in 1993, signed an agreement for a South American communications satellite. Two Canadian satellites provided an interim service beginning in 1993.

Nahuel series

Nahuel **(Fig. 16-25)** will serve the southern part of the South American continent for the first time with high performance links. Launched in January 1997, the satellite provides television distribution, telephone, data and business services.

This contract also included the construction of a ground control station in Argentina. This control station is located near the capital, Buenos Aires, and was approved for operations in November 1996. Since then, over 50 technicians have been trained in satellite operations. The station is designed to control the operation of three satellites.

Fig. 16-25. Nahuel 1A

SUMMARY

The expansion of ROW countries into space will continue. Communications and Earth observations are expected to lead the way for new entries into the list of space using nations.

For emerging nations with inadequate or antiquated communications infrastructure, satellites are an ideal way of rapidly acquiring a modern communications capability.

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